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Battelle Technical Review

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Ion Exchangers and Industry

V H T CERAMIST

JOHN A. SLYH

The technologist knows that the performance of atomic reactors, jet and rocket motors, as well as many industrial processes, could be improved if it were possible to raise operating temperatures. But the high-temperature properties of available materials often place upper limits on allowable operating temperatures which, if they could be increased, would contribute improved performance and efficiency. John A. Slyh believes that ceramic technology and ceramic materials may meet this VHT (very high temperature) challenge.

Jack has been a member of the Battelle staff since 1946. During this period he has carried on and directed research principally in two areas—super-refractories and building materials. Much of his work on VHT ceramic materials has been under the sponsorship of the Atomic Energy Commission and the U. S. Air Force. In the field of building materials his research relates to lightweight aggregates, concretes, limes, structural clay products, mortars, and water-proofing compounds.

Earlier, while with the Union Carbide and Carbon Company, Jack had worked on carbons and graphites for electrodes, seal rings, and corrosion-resistant equipment and helped develop catalytic materials for protective devices for use in chemical warfare. He was also responsible for the company's research on special refractory problems. Jack is a graduate of The Ohio State University and received his degree in ceramic engineering in 1935.

On April 28, this year, Jack received recognition for his contributions to the ceramic field. He was awarded a coveted Fellowship in the American Ceramic Society.

In addition to his technological activities, Jack is intensely interested in the fundamental methodology of science and devotes much time to a study of the problem. Any free time is automatically disposed of by his baby daughter, and his golf game suffers accordingly.

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The Cost of Research

ALTHOUGH MORE money is now being spent on industrial research than ever before, the cost of research to the ultimate consumer of the products of industry is minor.

This is made obvious by a consideration of research and production statistics. Last year, according to estimates made by the National Research Council, total U. S. research exceeded three billion dollars. More than half of this was spent on the development of military information and products. If 1.5 billion dollars is taken as the expenditure for research directly affecting civilian goods and services, and if this is divided by the 1952 estimate for the value of manufactured goods and services (360 billion dollars) we get a figure that represents the average percentage cost of research. That figure indicates that research accounts for less than one-half per cent of the cost of goods and services.

This is a low price for the consumer to pay for what he gets from research. An average research cost of one-half cent per dollar of sales is far less than the cost of the paper work in the transaction of most sales. In many localities the tax levied on the sale of the product is much greater than the research costs that made the sale possible.

Considering the costs of materials, labor, capital, distribution, and taxes, research is a real bargain and the "best buy" for consumers. It represents but a small part of the price of the finished product, and yet its effect may have been to lower the price of the product several times. In many instances it has also created the job that gave the consumer the money to make the purchase.

The fact that we have progressed so far industrially in this country with the expenditure of such a minor proportion of the sales dollar on research only enhances our appreciation of the potency of research. If one-half per cent can bring about the development we have experienced, what could we achieve if we were really pressed and willing to spend several times this much?

As yet, in our industrial economy there are few, if any, instances of research being pushed to the economic limit in order to accomplish a goal. It is doubtful if any industry—taken as a whole—has ever approached the point of diminishing returns with its research expenditures. Yet in other facets of production and distribution, we habitually operate close to points of diminishing returns and consider it good business policy.

The fact that we have a vast unexplored margin before research costs could become limiting factors means that we have great room for future progress. It means realistic possibilities for business expansion, the maintenance of a dynamic economy, and the solution of technological, economic, and social problems.

The relatively low cost of present-day research the solution of technological, economic, and social problems.

Director, Battelle Memorial Institute

Ion Exchangers and Industry

by GARSON A. LUTZ

Dr. Foster, who directs research in combustion and physical chemistry at Battelle, was appointed to the Institute staff in 1943. He is author of several articles and coeditor of the book, "Economics of Fuel Gas From Coal". In addition to his investigations into fuel problems, the author is guiding research into new areas of inorganic chemistry. He is an active member of the American Chemical Society and of the American By-Product Coke Institute.

AN IMPORTANT PART of the Plutonium Project in its early stages was an investigation of the radiotoxicity of fission products and of the hazards of handling them. The fission products from the pile, however, were difficult to work with. The major fission species of the rare earths were better suited for working out a process of separation for detailed study of the physical, chemical, and biological problems involved. Though only small quantities were needed, the scientists at the Oak Ridge (Clinton) National Laboratory had to find a way of producing the rare earths in the highest purity.

Of the possible methods of separation, the scientists chose ion exchange as the most promising. Experimentation finally resulted in the discovery of an ion-exchange technique which made possible the separation of the desired rare earths in purities of 99.99 per cent.

This example of what can be accomplished by means of ion exchange suggests why the process is becoming increasingly important in industrial fields. It provides more efficient and economical means for carrying on numerous manufacturing processes.

HISTORICAL BACKGROUND

One of the first recorded applications of ion exchange is found in the Bible. When Moses brought the Israelites from the Red Sea and led them into the Wilderness of Shur, they existed three days without water. On reaching Marah, they found the water undrinkable. Thereupon, Moses cast a tree into the waters. The waters at once lost their bitterness and the Israelites were able to drink them. Probably unknown to the great leader, the event marked the first recorded application of ion exchange. Beginner's luck was with Moses because variables such as solvent, temperature, acidity of the solution, and equilibrium were favorable.

Probably the earliest recognition of what is involved in ion exchange came with the observations of two English agricultural chemists, Way and Thompson, in 1848. They found that on treating soil with water-soluble fertilizers such as ammonium carbonate and ammonium sulfate, the ammonia was absorbed and lime was released. Way concluded that zeolites in the soil were responsible for the exchange.

It was not until about 1900 that zeolites were used industrially for softening water and purifying sugar solutions. Zeolites available at that time were not stable enough to be used even in moderately acid and alkaline solutions. A long step forward was taken in 1935 when Holmes prepared exchange resins which were fairly stable under acidic and alkaline conditions. Not only were the exchangers stable, but also much more efficient than zeolites. Moreover, they could be regenerated for repeated use. Holmes's exchangers were the forerunners of the very efficient resins now commercially available.

MECHANISM OF ION EXCHANGE

An ion-exchange resin is a large, porous, insoluble molecule which contains reactive groups on its surface. The resin is capable of trading equivalents of anions and cations in these groups for anions and cations dissolved in, for example, water. To meet some of the practical requirements of the ion-exchange process, resins must be insoluble and also be capable of being regenerated repeatedly, that is, converted to their original forms without appreciable loss of initial capacity. Furthermore, the resin should be chemically and physically stable during all operations.

To assure the rapid exchange of ions on the surface of the resin with ions in solutions, the resin should be porous and should swell to its maximum extent in order to expose as much surface as possible. Many of these requirements have been achieved by the chemist. Besides, he has developed weak-medium-strong acid

and weak-medium-strong base type exchangers comparable to acid-base systems in inorganic and organic chemistry.

Techniques of Ion Exchange

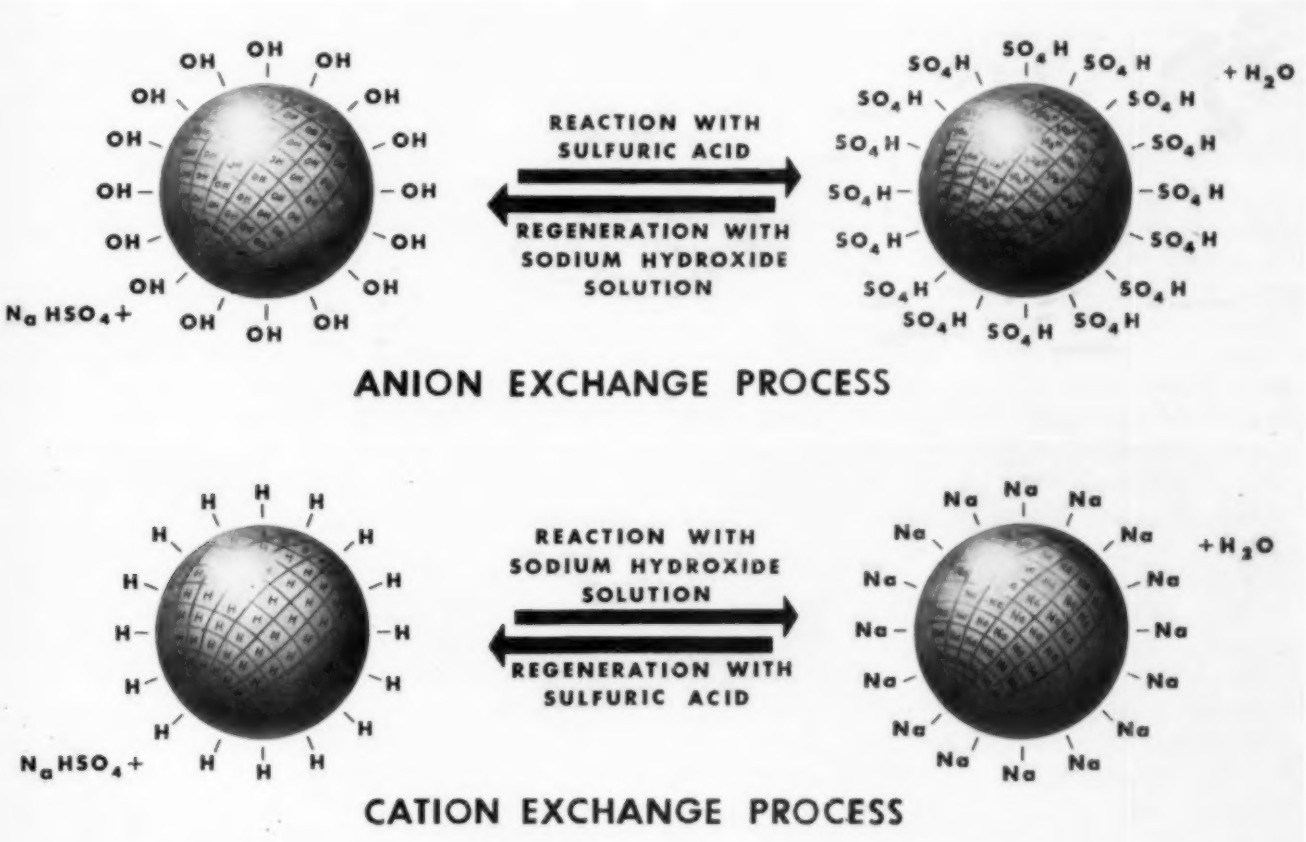
The rapid development of ion-exchange applications can be credited to chemical research, which has led to the commercial availability of excellent exchangers, and to engineering research, which has given us equipment adaptable to almost any scale of exchange operation.

Ion-exchange operations may be carried out by both batchwise and column methods. In batchwise operations the exchanger is merely stirred with the process solution, which contains the ion, A, to be removed or recovered. When the resin has picked up, by exchange with the solution, the desired amount of ion A it is separated from the solution by filtration or otherwise. More resin is added to the process solution and the process is repeated until the solution is as free of ion A as is desired. This is determined by analysis of the original solution and of the processed solution.

A one-cycle column operation can achieve results equal to an almost endless repetition of batchwise operations. When an electrolyte solution is passed downward through a column packed with exchanger, the exchanger bed will become saturated with ion A at the top first and then progressively downward. In this way there will be enough fresh exchanger to come in contact with the lean electrolyte.

In general, if column dimensions, flow rate, solution, temperature, and other factors for a particular operation are suitable, the solution flowing from the ion exchanger will contain the ions displaced from the resin by the ions of the same charge in the original solution. The process will continue until the resin in the column becomes nearly saturated with the ion being removed from the solution. If more of the solution is introduced, the exchange of ions will stop. At

These sketches illustrate the mechanism of the ion-exchange process. The upper diagram shows how sulfuric acid reacts with an anion-exchange resin, R-OH (where R represents the insoluble portion of the resin), to yield water and the acid salt of the resin. The lower diagram illustrates the reaction of sodium hydroxide with the cation-exchange resin R-H (where R represents the insoluble resin) yielding water and the sodium salt of the resin.



this point the solution may be switched to a fresh column and the exchange continued.

In analytical work it is frequently desirable to operate well below the break-through point. This is particularly true if the absorbed ions are to be analyzed by chromatography. Sometimes it is feasible to use anion- and cation-exchange resins in successive columns or in the same column. These variables are discussed below.

Treatments of Water

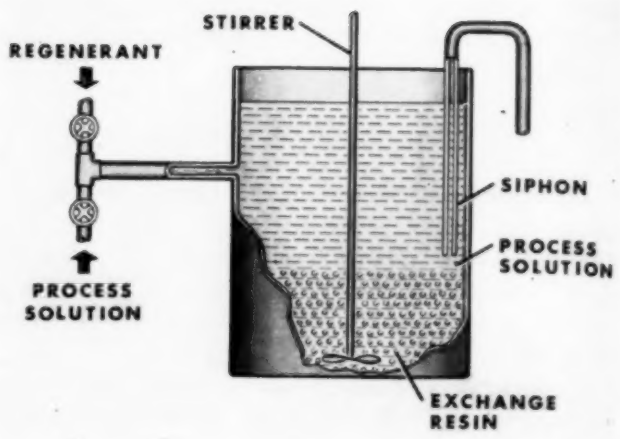
As more is learned about the science of ion exchange, the process can be applied to new applications. New resins and equipment are constantly being developed to make possible the employment of the ion-exchange process in more and more industries. The new knowledge is also resulting in the improvement of existing processes.

The treatment of water is still the major application of ion exchange. Sodium cycle, split-stream, and deionization methods are being employed. In the sodium cycle method, hard water is passed through an ion exchanger in the sodium form. As a result, calcium and magnesium are removed by exchange with sodium.

In the split-stream method, the water is divided into two streams. One of these passes through a hydrogen exchanger to remove the divalent ions and generate sulfuric and carbonic acids. The other stream is passed through a softener, the sodium exchanger. A softened water results as the two streams are again brought together.

Deionization of water is useful in cases where salt-free water is required. Water for the washing of phosphors for use in the manufacture of television and communication tubes must be very pure and is prepared by deionization. In most cases, the deionization of water is achieved by percolating it through separate columns of anion and cation resins in series or through a mixed bed containing an equivalent quantity of a strong base anion exchanger admixed with an equivalent quantity of a cation exchanger. In some cases, colloidal and suspended substances cannot be removed by ion exchangers. It may be necessary, then, to employ coagulation, filtration, or sterilization procedures prior to ion exchange.

Mixed-bed deionization is a recent and effective method of treating water. The purity of the water treated by this method may be such that its electrical resistance is greater than 2,000,000 ohms per centimeter. It has been claimed that mixed-bed deionization has advantages over conventional multiple-bed techniques which include lower costs of equipment and operation, better control of the quality of treated solutions, and more uniform performance.



In batchwise operations, the process solution is added to the resin. The mixture is then agitated until the ion-exchange resin is spent. If removal of the ion is incomplete, the process solution may be transferred to additional tanks and process repeated until the desired removal has been achieved. The resin in the tank can be regenerated for further use.

Other Industrial Applications

Next to water purification, the largest single use of ion exchange is in the refining of sugar. The principal purpose of the ion-exchange treatment in this industry is to increase the yield of white sugar and decrease the amount of sirups. Deionization is employed to remove ash constituents, amino acids, and color-producing bodies from a number of products. It is used in connection with beet and cane sugars, sorgo juice, black-strap molasses, edible sirups from fruit wastes, pectin from grapefruit peel, and tartrates from winery wastes. The inversion of sucrose solutions which utilize cation-exchange resins as catalysts appears promising as a means of preparing edible sirups.

Some of the most spectacular applications of ion exchange have been in the separation and reclamation of metals from virgin solutions. The inorganic chemist may recall the painstaking efforts that were required only a short time ago to obtain small quantities of "pure" rare earths. Fractional crystallizations frequently took years. Today, the pure individual rare earths are not rare.

The greater abundance of these formerly rare substances may be credited to the classical work of the research teams connected with atomic energy developments as described at the beginning of the article. By using monazite sands and pile products as raw materials, these investigators achieved quantitative separation of rare earths, fission products, and other metal ions on ion-exchange resins. The development of specific complexing agents for combining with and removing the ions and the adaptation of tracer techniques in the analysis of the resulting materials made

possible the isolation of the rare earths in high purity.

Ion-exchange methods have been investigated in the recovery of chromium, copper, and zinc from pickling and electroplating solutions. Metals such as arsenic, chromium, molybdenum, palladium, platinum, silver, and vanadium can be reclaimed by adsorption of their negative complexes. Molybdenum and rhenium, found in the flue dust from molybdenite roasters, may be separated by the use of ion exchangers. Considerable work has also been done on the recovery of strategic materials from brines and sea waters by ion exchange.

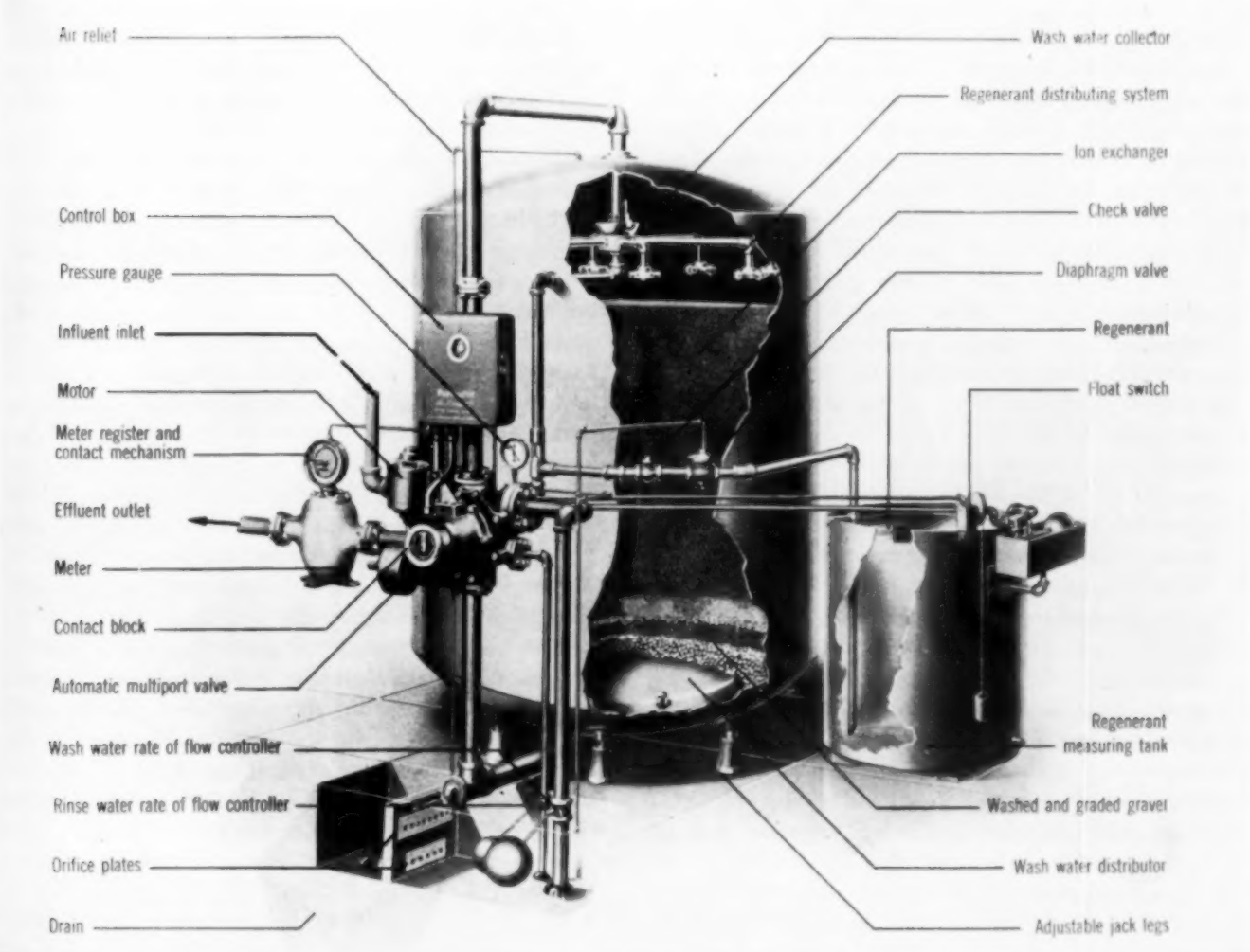
An important new development is the use of ion-exchange resins in the process that is being applied for extracting uranium from gold ores at South Africa's gold mines. In this process, the uranium is leached from the ores by means of sulfuric acid which can be made from pyrites found in the area. The resulting solution is then passed over ion-exchange resins to obtain the uranium.

Ion-Exchange Resins in Catalysis

Ion-exchange resins serve as catalysts in certain chemical reactions. Their use in industrial processes has been reported in connection with such reactions as the inversion of sugars, hydrolysis of esters, and oxidations, hydrogenations, condensations, dehydrations, and dehydrohalogenations of organic compounds. The petroleum industry has investigated ion exchangers in desulfurization processes.

The advantages of insoluble exchangers over soluble acids and bases in catalytic reactions are that the reaction products are free of either acid or base, the

This cutaway view of a zeolite water softener illustrates a percolating or column type of ion-exchange operation. Knowing the hardness of the water, it is possible to meter the amount that can be treated before exhaustion of the resin. The tank at the right contains a solution for regenerating the exchange after its exhaustion. (Courtesy of The Permutit Company)



catalysts can be reused, and the side reactions are minimized.

The importance of preparing pure catalytic materials has caused manufacturers of the materials to turn increasingly to ion-exchange methods of preparation. Acid oxide sols of molybdic, silicic, and tungstic acids, and hydrous oxides of aluminum, cobalt, iron, nickel, and vanadium, which are often used in catalytic and analytical processes, usually have been prepared by precipitation and dialysis techniques. Recently, these materials have been obtained in a high state of purity by using ion exchangers for the removal of soluble electrolytes.

Medical Applications

A number of interesting recent uses of ion exchangers are to be found in the field of medicine. For example, the ion-exchange process may be very helpful in ulcer cases. Ulcer formation and ulcer pain apparently result from mucosa erosion, activated by pepsin and hydrochloric acid. Anion-exchange resins can be used to inactivate pepsin by decreasing the acidity of the stomach, thus bringing about a condition unfavorable to continued existence of ulcers.

A cation-exchange resin containing a quinine cation has been used to determine free gastric acidity in the stomach. About 20 per cent of the exchanged quinine is excreted in the urine if the free acidity exists. Assay of the urine for quinine indicates the hydrochloric acid content of the stomach. This technique is believed to be valuable in the diagnosis of stomach cancer, pernicious anemia, and gastric polyps. Cation-exchange resins have also been employed in the fixation of dietary sodium in the gastro-intestinal tract in most cases of high blood pressure, and for the prevention of excess fluid in tissues, excessive tissue formation, and kidney ailments. Anion-exchange resins have been effective in the elimination of heartburn during pregnancy.

Ion exchangers have been utilized for the control of media during studies on the effect of trace elements on the metabolism of microorganisms. Gallium citrate, valuable for the treatment of bone cancer, has also been obtained in high purity with ion exchangers.

A technique for the partial purification of the Lansing strain of poliomyelitis virus, which uses ion exchangers, permits a tenfold increase in virus concentration in contrast to sharp decreases obtained with older procedures.

Amino acids obtained in the hydrolysis of proteins have been separated and the purification of albumin, alkaloids, antibiotics, hormones, insulin, blood plasma, and vitamins has been improved by ion exchange and ion-exchange chromatography. The same process has been applied to the removal of sodium from milk, copper from milk and petroleum, nickel from sugars, sulfuric acid from antifreeze and formalin, and salts from glycerin sweet waters.

Future of Ion Exchange

The development and increased use of ion-exchange processes in many applications may be looked for in the near future. Exchangers that operate at higher temperatures and have longer life, greater capacity, and greater specificity will emerge from the research laboratories. Much more will be heard about ion-exchange resins in film, belt, and membrane form. Some resins fabricated in this manner can be used in continuous operations where chemical regenerants are not required since the processes are accomplished by electrical energy. Another outstanding property of these resins is permeability to ions of one charge and impermeability to ions of opposite charge. The deionization of water, the upgrading of ores, and the purification of metals, chemicals, pharmaceuticals, and beverages will be improved by resins that show selective permeability for ions.

The deionization and the softening of water will continue to enjoy the number one spot in the ion-exchange industry. Universal application of deionization and softening techniques can be visualized. Municipal drinking waters, soft water for laundering, control of dental caries, the deposition of television phosphors, and milk production will continue to be improved by chemical and engineering research in water conditioning. The development of domestic cartridges containing a mixture of anion and cation resins will aid in the sale of millions of "drip type" steam irons. In 1952, an average American family using water of low hardness spent about $190 on soap, water heater fuel and service, fabrics, and plumbing. Where water contained 20 grains per gallon of hardness, a similar family spent about $330.

The research scientist will develop many new ion exchangers and find new and improved applications for them and for currently available exchangers. He will not always be as lucky as Moses. However, he has a wide choice of commercially available exchangers and many raw materials from which to prepare tailor-made exchangers.

Energy for the Future

by JOHN FARLEY FOSTER

The author's field of specialization is organic chemistry, particularly resins, fatty acids, ion exchange, and petroleum. He joined Battelle in 1945 after serving as organic research chemist with the Solvay Process Company, the Blaw-Knox Company, and the United Gas Improvement Company. Dr. Lutz received his doctorate in organic chemistry from Northwestern University in 1937. He is a member of the American Chemical Society.

FEW OF US FULLY realize the key role that fuels and energy play in our lives. An adequate supply of energy is perhaps the most important factor in the advance of our technical civilization. Without it our industrial system would grind to a stop. Unless we can continue to increase our power supply, many technical improvements may be held in abeyance.

The full meaning of the importance of energy is well illustrated by a recent movie, "The Day the Earth Stood Still." The central character is a visitor from another planet who came to earth to assure peace. He found it necessary to demonstrate to skeptical earth men the authenticity of his origin and the seriousness of his mission. At a specified hour, the visitor announced that something would happen to establish his identity and purpose beyond all doubt.

And happen it did. When the time arrived, all power-requiring activities on earth stopped for half an hour. From Washington to London, Bombay, Shanghai, and San Francisco, life came to a virtual standstill. The space visitor had signalled his planet to neutralize all power on earth.

This, of course, is an extreme example of what power means to modern civilization. Most of us, however, are inclined to take our power supply for granted. Fortunately, science and industry are constantly working to ensure us an adequate supply of energy-giving fuels. This is being done by adding to fuel reserves through exploration and through finding more efficient and economical ways of using existing fuel supplies.

In the past 25 years, this teamwork has enabled an unprecedented expansion in our economy. It has made it possible, for example, to increase our electric power output sixfold, to 370 billion kilowatt hours.

In the next quarter-century, it is estimated that the country will develop a need for 60 per cent more steel, perhaps 200 or 300 per cent more aluminum, and three to four times as much electric energy. We are confident that the industry-science team will ensure a fuels supply adequate to meet these and other needs.

One of the brightest spots on the fuels horizon is natural gas. Present production supplies nearly 20 per cent of the nation's total energy requirements, or more than double the share of 25 years ago. Vast reserves are already known. The most pressing problems are to provide economical means of transporting more of the gas to distant markets, and to develop low-cost methods of storage at the point of use. Ways of solving both of these problems are being actively sought.

Natural gas is particularly adapted to the needs of the small consumer. The residential market, which currently accounts for 20 per cent of total natural gas consumption, may increase as much as two times during the next 25 years. This rapid rise will probably be accompanied by a slower rate of increase in industrial uses.

CONTINUING IMPORTANCE OF COAL

No long-range program for strengthening the country's energy position can overlook the key importance of coal. It is still our basic fuel resource. Coal supplies about 40 per cent of the country's total energy requirements.

A large portion of the rapidly expanding fuel requirements of the power-generating industry will be met by coal. Advances in fuel-burning equipment such as the spreader stoker and the cyclone furnace will ensure satisfactory combustion of coals of a variety of ranks and of poorer quality.

The trend toward the use of diesel fuel instead of coal or residual fuel oil to supply the energy for railroad locomotives will continue. Sometime during the next 25 years, however, economic conditions may lead to increased use of coal through the manufacture of

synthetic diesel fuel, more extensive electrification, and the development of a coal-fired gas turbine.

Coal will continue to supply the basic energy for industrial heating and process steam. It will become increasingly important, indirectly, in the form of electricity for industrial furnaces. The development of automatic, coal-fired steam-generating plants may be achieved. These will include standard, packaged units capable of burning many grades of coal and equipped with mechanical coal-feeding and ash-removal systems.

Almost all of the metallurgical fuel will still come from coal. It may become feasible, economically, to derive even more chemicals from coal than now, either as by-products of coal's conversion to oil or gas or by direct conversion of coal to chemicals. Uses for fine coal, normally discarded, will be found.

Our supply of liquid fuels appears assured for an indefinite period of time. Crude oil is still the cheapest and most plentiful raw material for the manufacture of liquid fuels. Techniques have been developed, however, by which liquid fuels can be made from coal, natural gas, oil shale, tar sands, and various forms of vegetation. Should the cost of producing petroleum increase to a point where it is profitable to make an equivalent fuel from coal or other alternative sources, industry will be ready to assume the task.

Hydroelectric power resources supplied 27 per cent of the nation's electric energy in 1951. Unlike other power sources, hydroelectric power reserves are not depleted through exploitation. There are, however, two ways of improving on present usage. First, improvements in turbine design can be made, whereby more power can be generated from the same dollar investment in equipment. Second, private and government interests can more effectively coordinate hydroelectric power plants with other types of electric generating plants.

The total energy available from known reserves of coal, natural gas, petroleum, oil shale, and hydroelectric power is more than enough to meet the expanding needs of our economy. Industry and science, however, must continue to improve on the techniques of converting these known energy supplies to the most efficient and most economical end-power uses. Making the most of what we know we have is still the best insurance for an adequate power supply for the future.

"... by well-ordered empirical procedures it has been possible to make great progress in the practical arts. Such procedures are still being used in almost all branches of applied science. In metallurgy and organic chemistry, for example, the degree of empiricism is still high, but the development of new concepts and wide conceptual schemes was essential to the progress of physics, chemistry, and biology in the last three hundred and fifty years. As these sciences became equipped with more and more satisfactory theories, the degree of empiricism in the arts related to these sciences diminished. . . . The history of the last hundred and fifty years in particular shows what occurs when advances are made in pure science. New principles evolve which can be related to empirical observations; at that point it becomes possible to control with far greater accuracy than before what one is doing in the practical arts and to predict the outcome of a large-scale operation directed towards making a commercial product."

—From *Modern Science and Modern Man* by James B. Conant

Notes From Battelle

INCREASING IRISH PEAT PRODUCTION

Historically, peat has been an important source of energy for the Irish people. Peat bogs cover one-sixth of the nation's area. For centuries, the fuel has been dug from these bogs by hand, dried in the sun in the form of blocks or sods, and laboriously turned, stacked, and finally collected for use in cooking, heating, and small industry. Even today, this arduous hand labor of thousands of men, women, and children accounts for the production of some three-fourths of Ireland's annual production of four to five million tons of peat.

The Irish Turf Board introduced machinery for gathering sod peat after World War II. Mechanization has been so successful that two power plants that burn sod peat are now in operation. However, even the mechanical winning of sod peat requires more manpower than would be available with a future expansion of demand. The months from March through July that are dry enough for working the bogs are also those in which labor is required on the farms.

The Turf Board has also developed milling as a second method of harvesting peat mechanically. By this method, peat is literally torn from the surface of the bog by spikes mounted on a rapidly whirling drum carried on diesel-powered machines. The resulting fine-milled peat dries rapidly and can be gathered quickly by machines for transportation from the bog. Production per man is more than twice that by mechanical methods of gathering sods.

Under a research program arranged by the Economic Cooperation Administration, a Battelle team of fuel technologists and mechanical engineers studied the problems of fuel production and utilization for the Irish Turf Board. First, an examination was made of the Irish situation and of practices in other peat-using countries.

The use of milled peat in large boilers for power plants is much to be desired, and one of Battelle's special assignments was to recommend firing equipment for this purpose. On the basis of the survey of practices in other countries, the burning of the peat in suspension after pulverization in a German-developed Kraemer-type mill was recommended. The Irish Government accepted the recommendation and has ordered three boilers for a new 40,000 kilowatt station.

The successful burning of peat in an electrified, thermostatically controlled stove was demonstrated in the Institute's laboratories. The Turf Board's Experimental Station is pursuing this recommendation for use in kitchen ranges and is also extending the principle to boilers for heating and small industrial use.

TREATMENT OF TACONITES

The huge taconite deposits in the Mesabi Range can supply America's iron needs for years to come. However, the problems of raising the 25 to 35 per cent iron content of the taconites to high enough concentrations for use in furnaces have been a challenge to ore technologists for some time. The taconites containing iron in nonmagnetic form have presented a particularly difficult recovery problem.

A process for concentrating nonmagnetic taconites was described before the recent Blast-Furnace, Coke-Oven, and Raw Materials Conference of the American Institute of Mining and Metallurgical Engineers in Buffalo. In their paper, "The Reduction-Oxidation Process for the Treatment of Taconites," which received the *Journal of Metals* Award for the outstanding paper presented at the conference, Battelle technologists F. M. Stephens, Jr., B. Langston, and A. C. Richardson described a process developed at the Institute.

The process involves the conversion of nonmagnetic taconites to magnetic form by heating, followed by magnetic separation. This method has always been technically attractive because it permits high recoveries of iron from ores of widely varying mineral composition. However, the cost of the heat has been uneconomic. The new process may solve the problem of the high cost of heat by cutting down the amount of initial heat required and recovering and reusing that heat. Hydrogen and/or carbon monoxide have been found most suitable as reducing agents. Studies with a laboratory pilot plant show that the process can be applied to a wide variety of taconites including mixtures of hematite, magnetite, and siderite.

According to the authors, "The high recovery of iron units, 92 to 96 per cent, in magnetic form from ores treated by the reduction-oxidation process, plus the increased grindability of the processed ore, indicate that the process will be economically attractive. The savings in grinding costs may more than offset the cost of treating the ore by the new process".

The development of the "reduction-oxidation process" was one part of an over-all research project on the development of concentrating processes for the Mesabi taconites of the Lake Superior region. The study has been sponsored at Battelle over the past ten years by a group of iron ore producing companies.

RESEARCH AND PROGRESS

Expanding research facilities have played a leading part in the great technological progress of American industry. The importance of the independent laboratories in the research picture is not always clearly understood. We thought the subject was particularly well presented in a recent article in *Product Engineering* on "The Role of Independent Research Laboratories in Corporate Progress."

Independent laboratories are those not affiliated with the firms using their services. *Product Engineering* classifies them into four types: commercial laboratories and consulting firms; industrial laboratories that conduct research for outside companies as well as for their own company; universities and their research affiliates; and research institutes and foundations.

One of the reasons for the signifiance of the independent laboratories is that they give companies the advantages of large well-equipped and staffed laboratories without capital investment. Thus no company, regardless of size, need be deprived of opportunities for growth and development. At the same time, larger companies, with their own laboratories, find it worth while to turn over problems to the independent laboratories for solution.

The article presents some interesting facts on the costs of research. The Director of the Research Division of New York University estimates that a minimum research program will cost from $10,000 to $20,000. A study of January, 1953, research contracts at Battelle shows a range from $2,000 to $60,000, with the median at $12,000.

STUDY OF A CYLINDER IN ACTION

What happens in the cylinders of internal combustion engines is fundamental to their efficiency. Yet this is an area in which relatively little research has been done. However, a recent cooperative investigation by the Cooper-Bessemer Corporation and Battelle has done much to clear up what takes place when a motor is running. Results of the study were presented in a paper by R. L. Boyer and D. R. Craig of the Cooper-Bessemer Corporation and C. D. Miller of Battelle at the April 28 meeting of the Oil and Gas Power Division of the American Society of Mechanical Engineers.

The study was carried out on a Cooper-Bessemer GMV two-cycle, spark-ignited engine of 14-inch bore operating on natural gas. High-speed photographs were taken of the operating engine with the Isotransport Camera designed and built by Battelle. The photography was made possible by glass windows installed in the cylinder walls and heads of the engine.

Schlieren photographs were taken of combustion, exhaust blowdown, scavenging, gas turbulence, and fuel ignition. All of these phenomena were made clearly visible in slow-motion pictures. By this means, exact data could be secured for all gas and flame velocities as well as crank angles involved. Four thousand feet of 8-mm film was exposed during the study.

From the photographs it could be seen that exhaust gas during blowdown flows in straight lines. Scavenging air, however, was found to enter the cylinder in turbulent jets, thus mixing the scavenging air with residual combustion products. While such jet action was theoretically likely, its existence seems not to have been recognized earlier. Photographic proof of this phenomenon appears to be a significant contribution to the understanding of engine operation.

Since the elimination of oil to avoid its deposit on windows and mirrors was essential to good photography, a study of this problem became a part of the research. As a result, the discovery of possible improvements relative to oil consumption proved to be an important by-product of the investigation.

NEW APPOINTMENT

Dr. Charles M. Schwartz has been named to supervise research activities in X-ray and electron diffraction, and electron and light microscopy at Battelle. He has been a member of the Institute staff for thirteen years and has been long associated with X-ray and electron-diffraction work.

Schwartz received his doctorate in physical chemistry from Syracuse University in 1936. Previous to his association with Battelle he carried on special X-ray diffraction and crystal-structure studies at the University of Manchester in England and served as a chemist with King Laboratories, Incorporated.

Dr. Schwartz is serving as secretary of Subcommittee II of Committee E-4 on Metallography of the American Society for Testing Materials. He was formerly chairman of the Committee on Identification of Corrosion Products of the National Association of Corrosion Engineers and Director of the Electron Microscope Society of America.

RECENT PAPERS AND ARTICLES BY THE RESEARCH STAFF*

Mass Transfer in Packed Beds at Low Reynolds Numbers. C. E. Dryden, D. A. Strang, and A. E. Withrow. *Chemical Engineering Progress*, April, 1953.

A Preliminary Study of the Ductility of Chromium. H. B. Goodwin, R. A. Gilbert, C. M. Schwartz, and C. T. Greenidge. *Journal* of the Electrochemical Society, April, 1953.

What the Ferrous Metallurgist Should Know About Titanium. R. I. Jaffee. *Iron Age*, April 2, 1953.

Recrystallization of Wrought Hydrogen-Sintered Molybdenum and Its Alloys. M. H. LaChance, W. L. Bruckart, C. M. Craighead, and R. I. Jaffee. *Transactions* of the American Society for Metals, 1952.

The Welding of Thick Plates of High-Strength Aluminum Alloys. D. C. Martin, M. I. Jacobson, and C. B. Voldrich. *Welding Journal*, April, 1953.

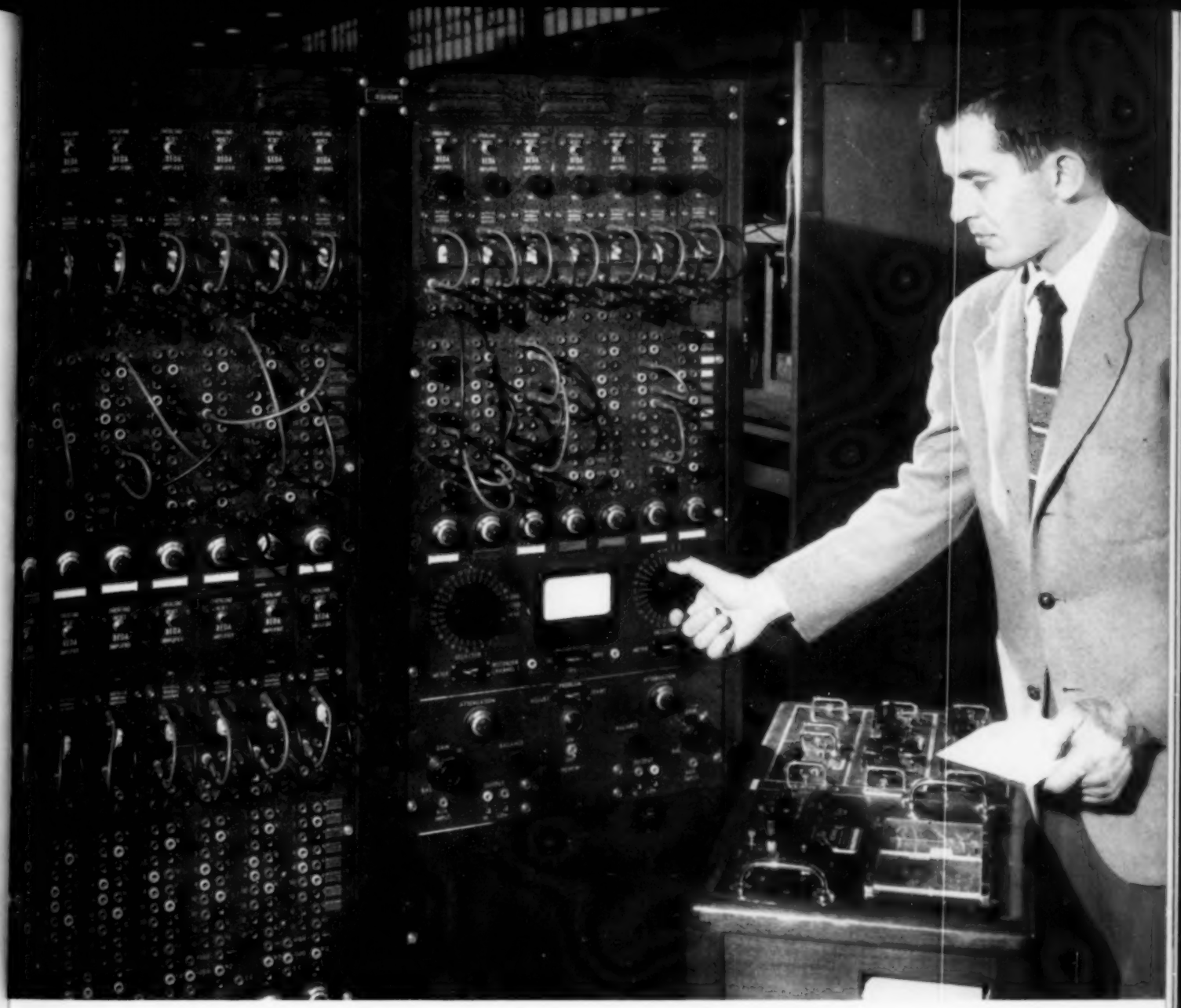
Vanadium-Uranium Constitutional Diagram. H. A. Saller and F. A. Rough. *Journal of Metals*, April, 1953, and American Institute of Mining and Metallurgical Engineers *Transactions*, 1953.

Low Grade Ores. J. D. Sullivan and S. F. Ravitz. *Machinery Lloyd* (Overseas Edition), March 28, 1953.

*In most cases, reprints will be available from the Battelle Publications Office upon request.

A Word About Battelle Technical Review Abstracts

The abstracts that appear in the following pages are prepared from approximately 900 American and foreign technical journals, as well as from books and other literature received in the Battelle Library. Prepared by a professional staff trained in various technological fields, the abstracts are selected for their usefulness to the Battelle research staff. They are now being made available to technologists and scientists in industry and research in all parts of the world, through the pages of the *Battelle Technical Review*.



COMPUTER FOR DYNAMIC PROBLEMS

This Battelle-developed electronic analog computer is a valuable tool for the technologist. It gives him data for appraising a multitude of factors that may affect a mechanical system or help in solving involved thermal, chemical, electrical, and other physical problems. With the device, the technologist is able to select, mathematically, the best possible combination of characteristics influencing a particular device or operation. The computer will solve differential equations to the eighth order and three or four simultaneous second-order equations.

BATTELLE INSTITUTE was founded by the will of Gordon Battelle as a memorial to the Battelle family. The Battelles were among the first settlers of Ohio and were prominent in the development of the state's iron and steel industry.

Gordon Battelle, last of the family line, was impressed with the benefits to be derived from industrial research and left his estate for the building and endowment of an Institute "for the purpose of education . . . the encouragement of research . . . and the making of discoveries and inventions for industry." The Institute began operations in 1929.

As established Battelle provides, on a not-for-profit basis, the physical plant, equipment, and personnel for conducting research. The great bulk of it is applied research conducted for industry and government.

In keeping with its educational function, the Institute also conducts fundamental or basic research. The results of much of this research are published for the general encouragement of science and industry, and to benefit the public welfare.

Fields of research at Battelle include agriculture and practically all the industrial and engineering sciences.

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